

Optical Lattices at Otago University

More Stupid Tricks with Bragg Scattering

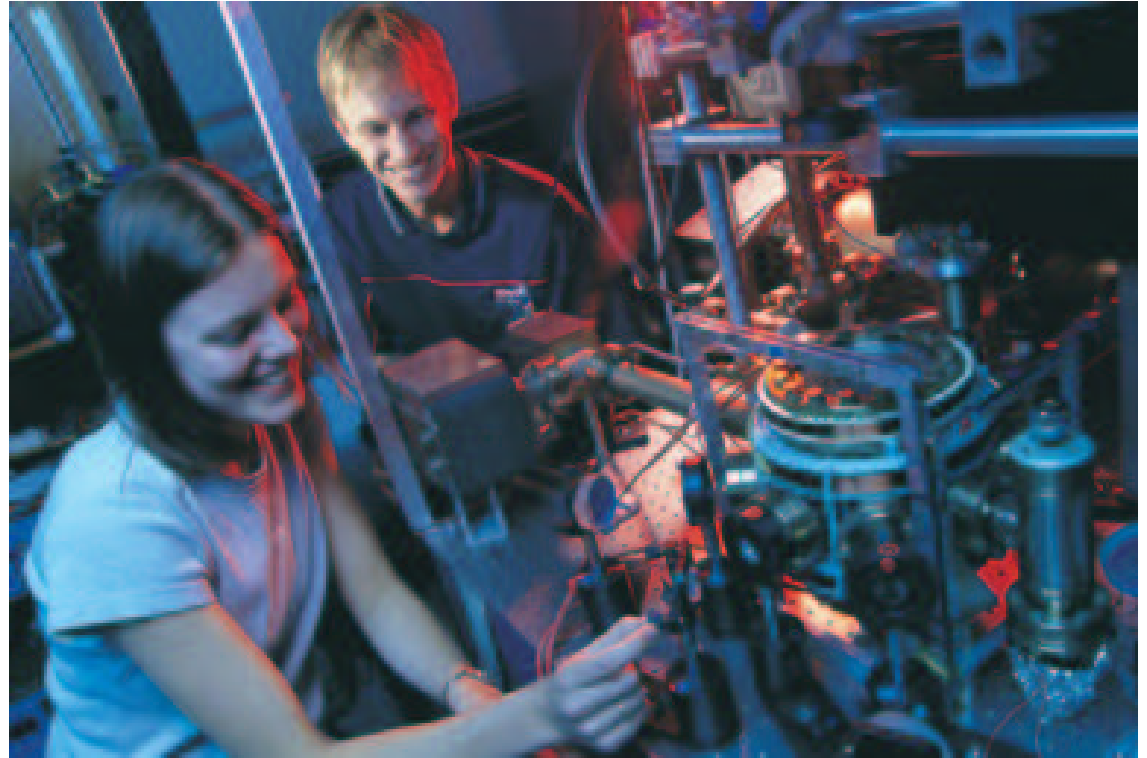
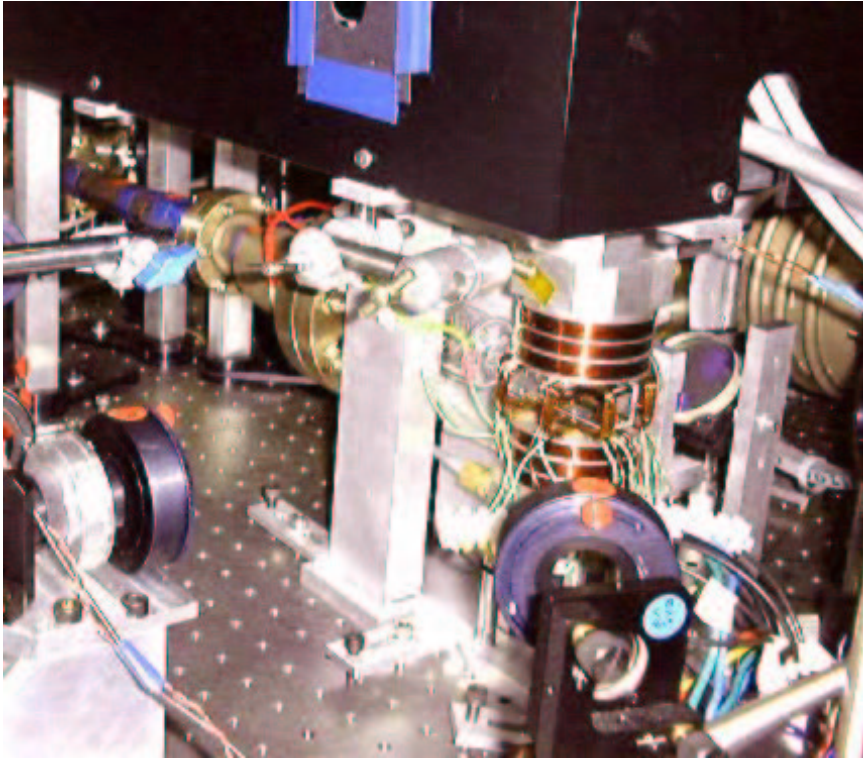
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Overview

- Phase Shifting the Lattice
- Loading the Lattice
- Micromotion

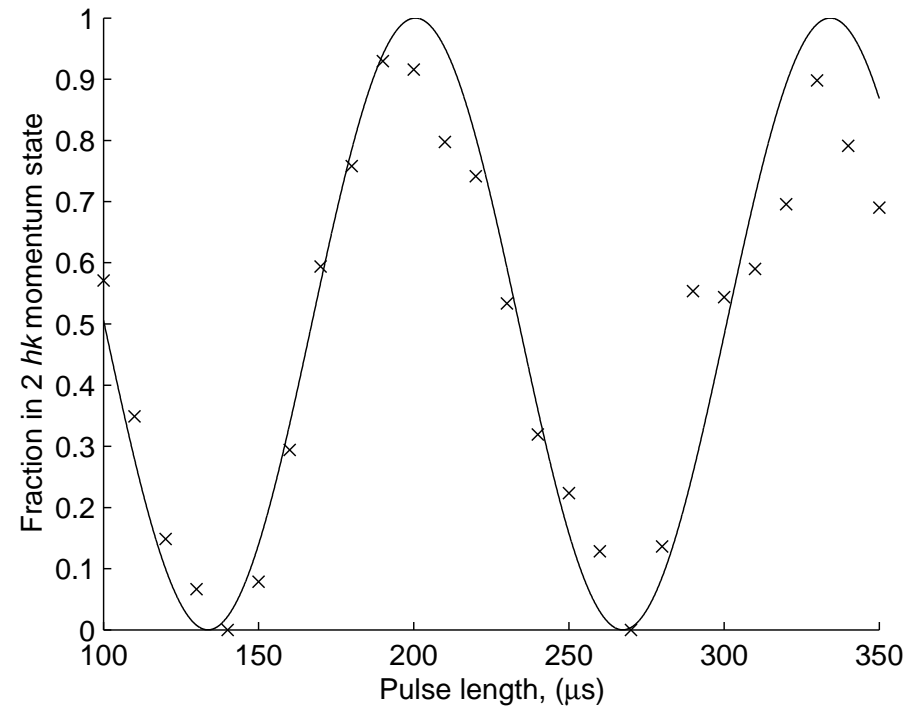
The Otago BEC Apparatus



- Double MOT and TOP trap.
- Injection locked diode lasers.
- Lattice beams provided by an MBR-110 Ti-Sapphire laser.

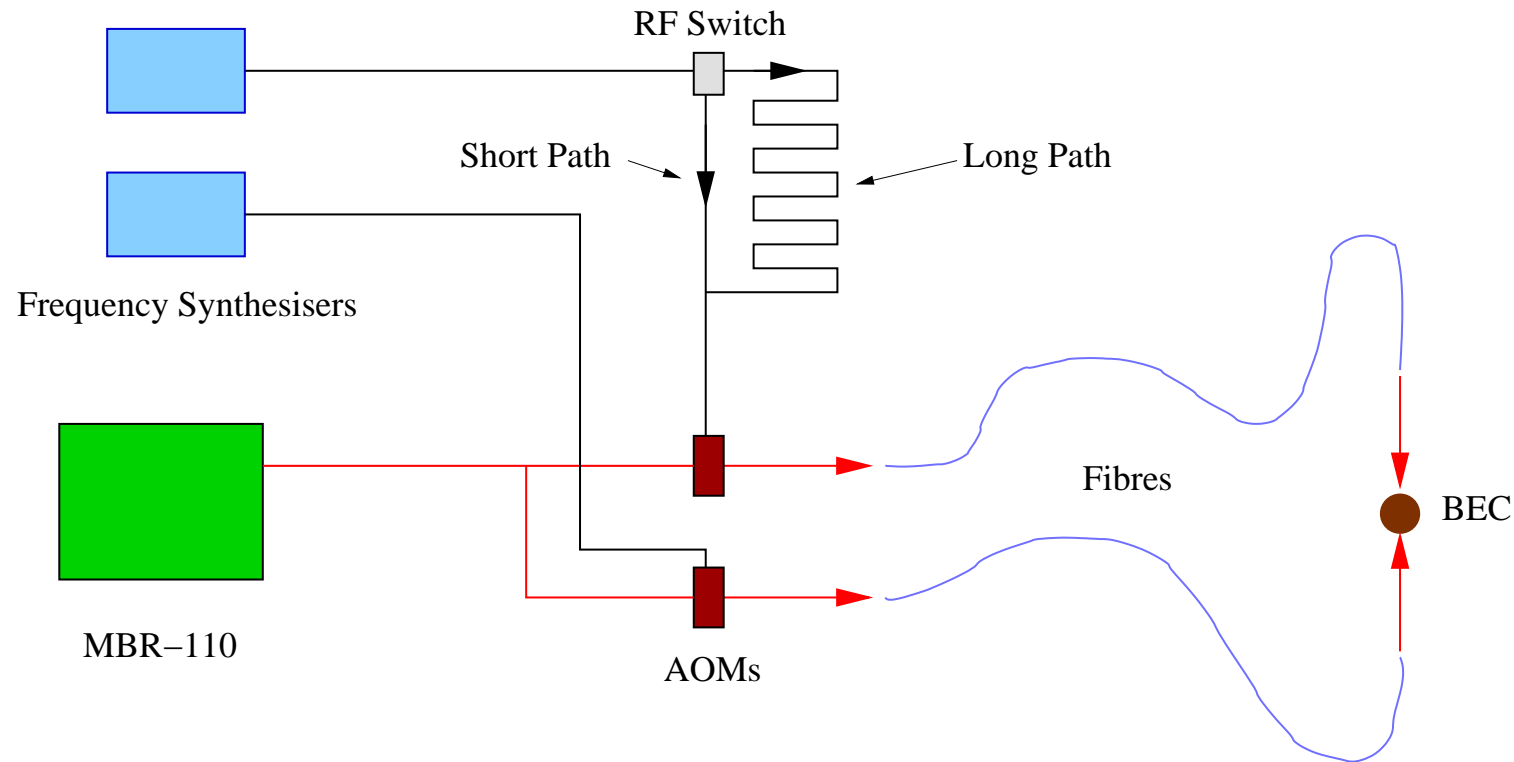
The System

An optical lattice tuned to the Bragg resonance.

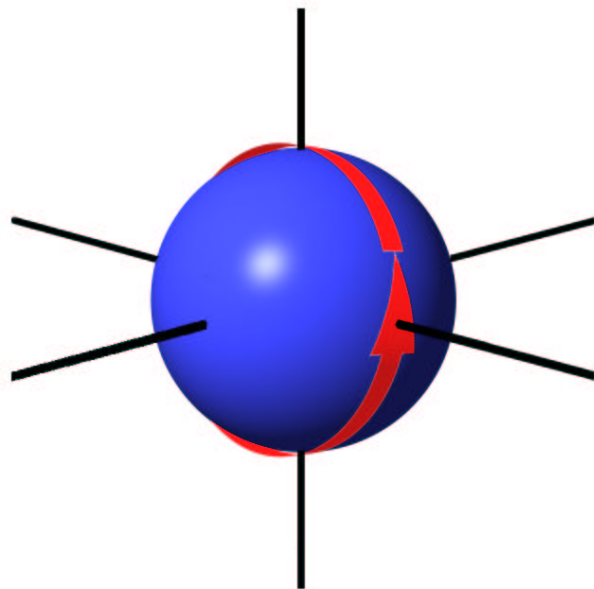


The intensity is low enough to limit the system to the 0 and $+2\hbar k$ momentum states.

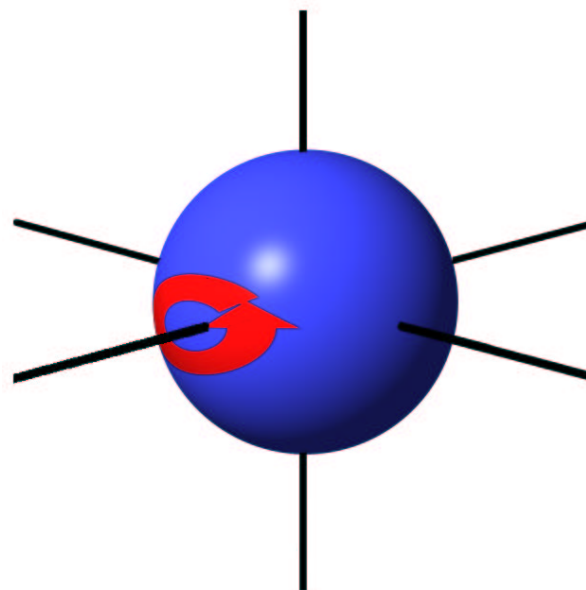
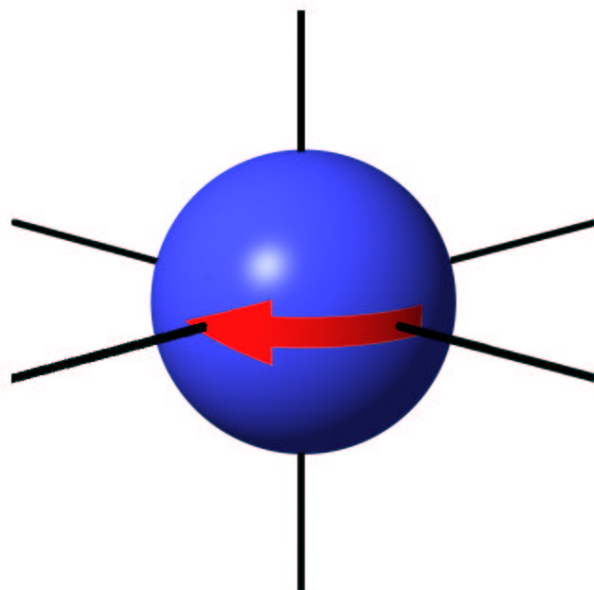
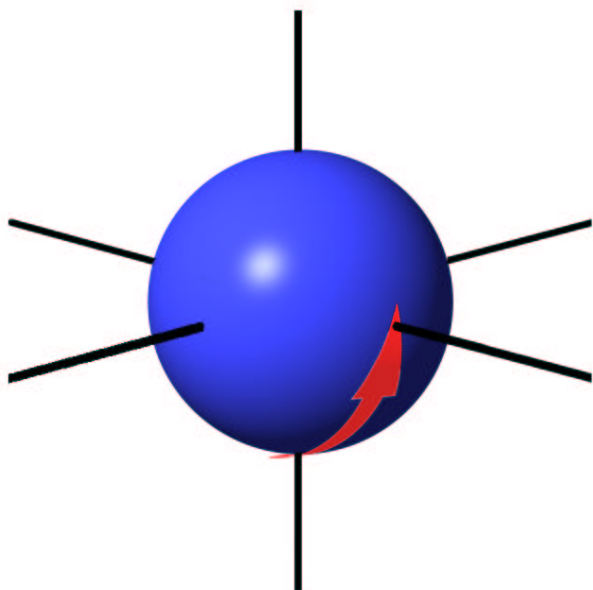
Phase Shifting the Lattice



A phase shift can be applied by suddenly switching the AOM signal between two different lengths of cable. The phase shift of the AOM signal gets translated to the light.

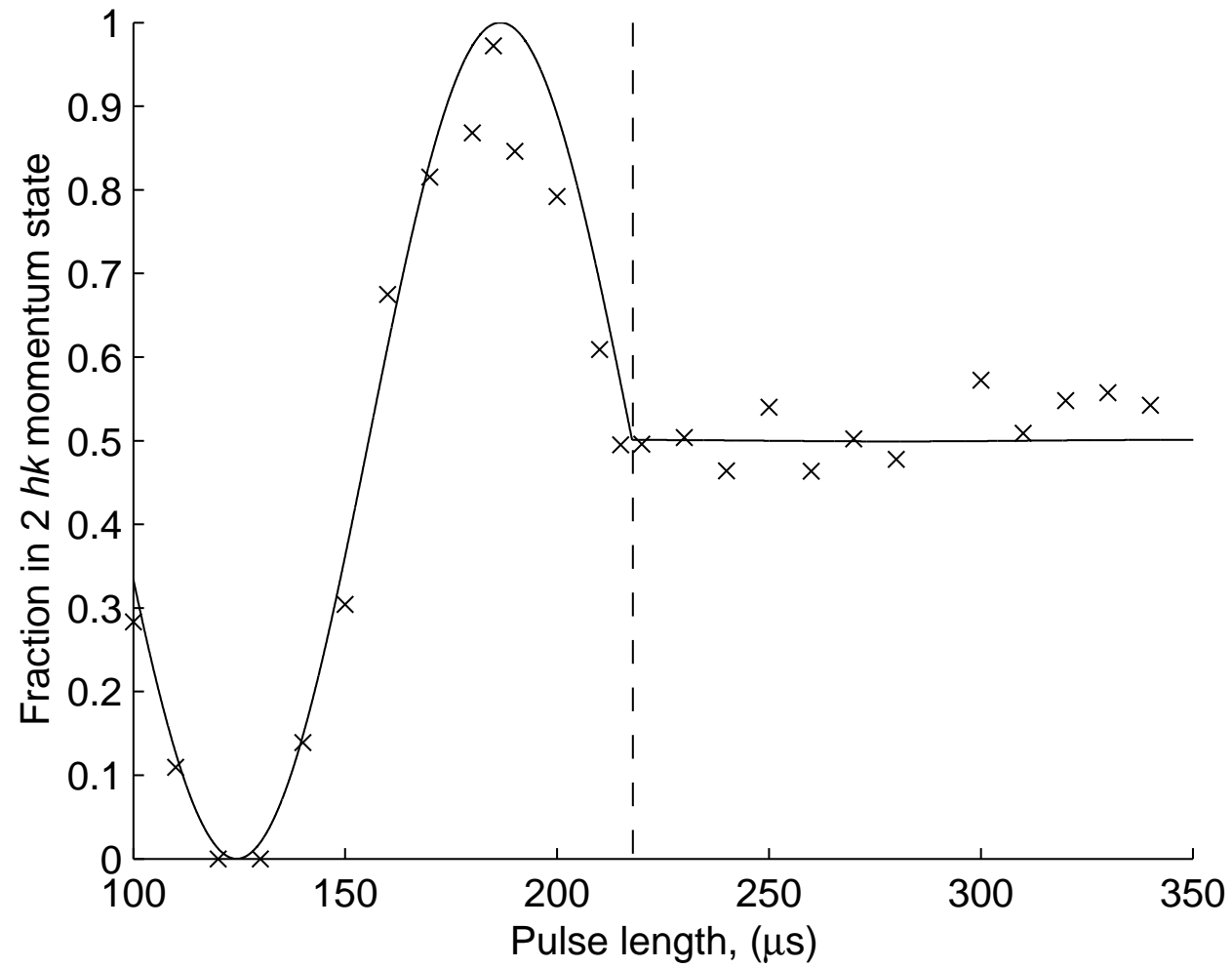


Rabi Flopping



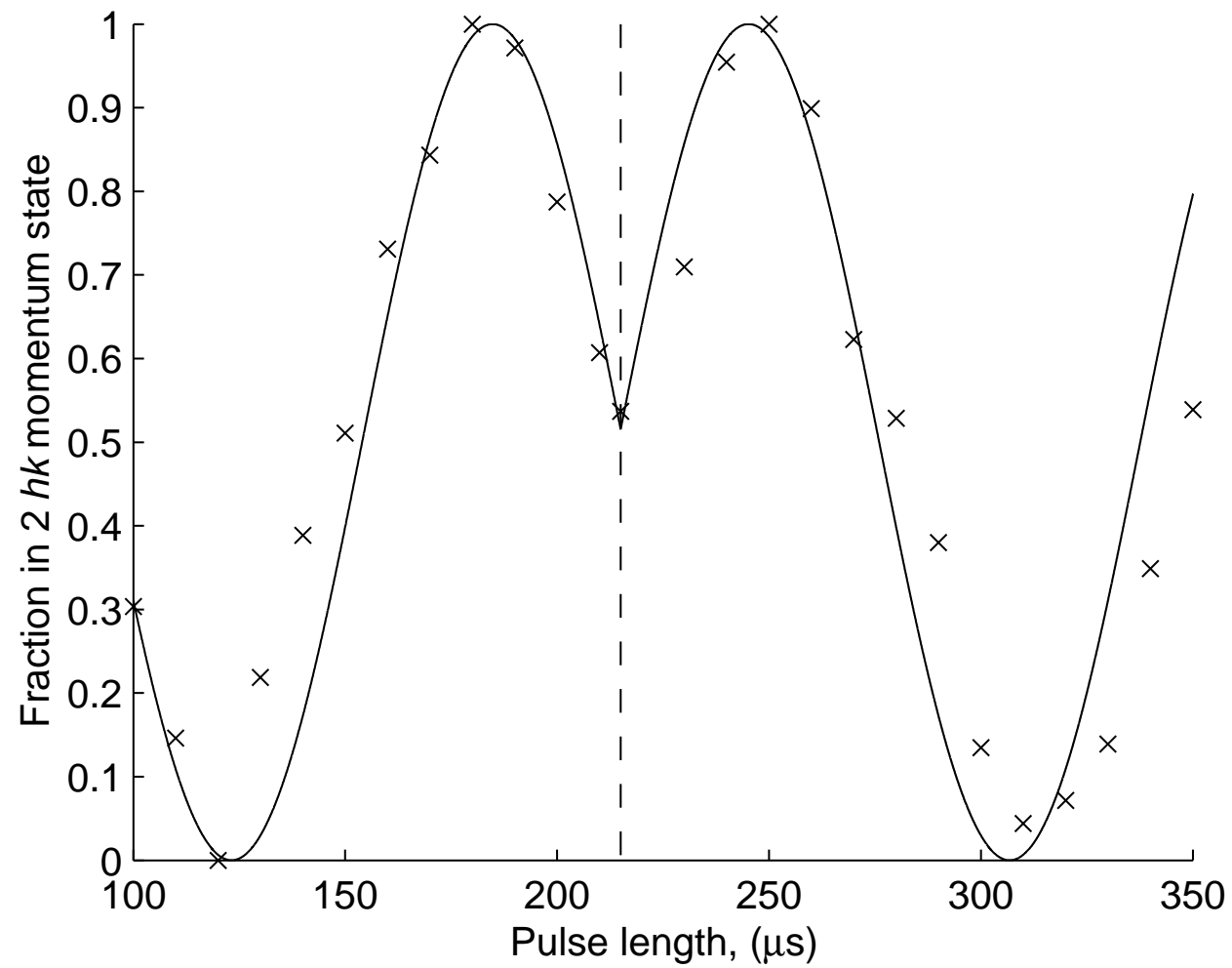
Suppressing Rabi Flopping

The Proof



Other Tricks

The π phase shift.



The Lattice Picture

To 1st order the first two lattice eigenstates are

$$\phi_0 = \frac{1}{\sqrt{2}} \{e^{ikx} + e^{-ikx}\} = \sqrt{2} \cos kx, \quad (1)$$

$$\phi_1 = \frac{1}{\sqrt{2}} \{e^{ikx} - e^{-ikx}\} = \sqrt{2} \sin kx. \quad (2)$$

Initial state

$$\Psi(0) = e^{ikx}. \quad (3)$$

so

$$\Psi(t) = \frac{1}{\sqrt{2}} \{ \phi_0 + e^{i\omega t} \phi_1 \}. \quad (4)$$

Applying a phase shift to the lattice at $t = \tau$ so $kx \rightarrow kx + \theta$ gives a new state

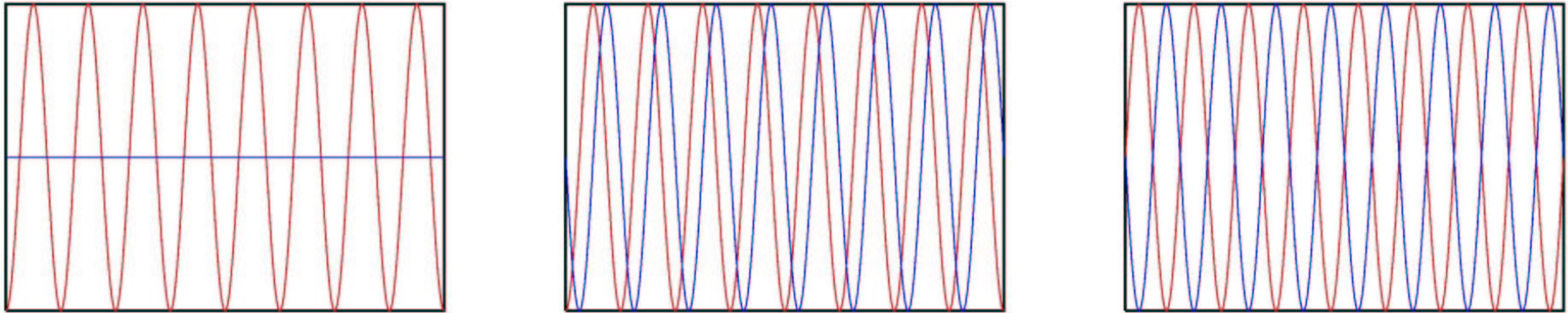
$$\Psi' = \frac{1}{\sqrt{2}} \left\{ (\cos \theta - ie^{i\omega\tau} \sin \theta) \phi_0 + (e^{i\omega\tau} \cos \theta - i \sin \theta) e^{i\omega(t-\tau)} \phi_1 \right\}. \quad (5)$$

So a $\pi/2$ pulse followed by a $\pi/4$ shift in the lattice beams gives

$$\Psi' = \phi_0. \quad (6)$$

In Pictures

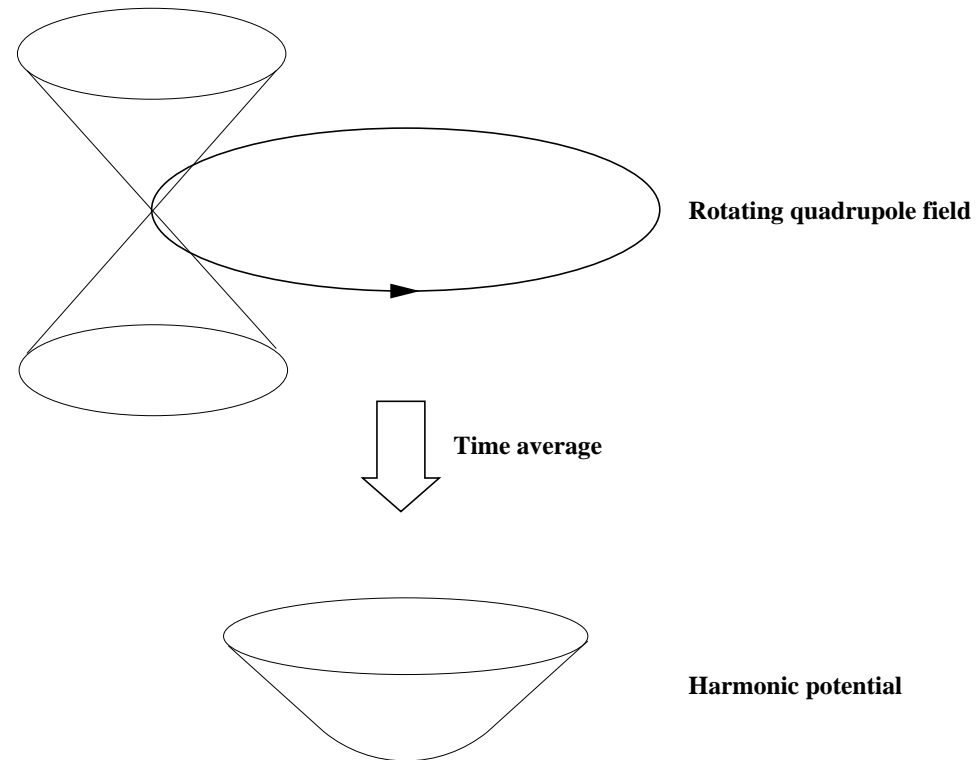
Red is the optical potential, blue is the probability distribution $|\Phi|^2$.



- When loaded the wavefunction is flat.
- It then oscillates from side to side.
- By shifting the lattice as the wavefunction reaches a maximum, we bring it into the bottom of the wells.
- We have now loaded the ground state.
- Loading the 1st excited state is also possible: shift the lattice the other way.

The Time Orbiting Potential

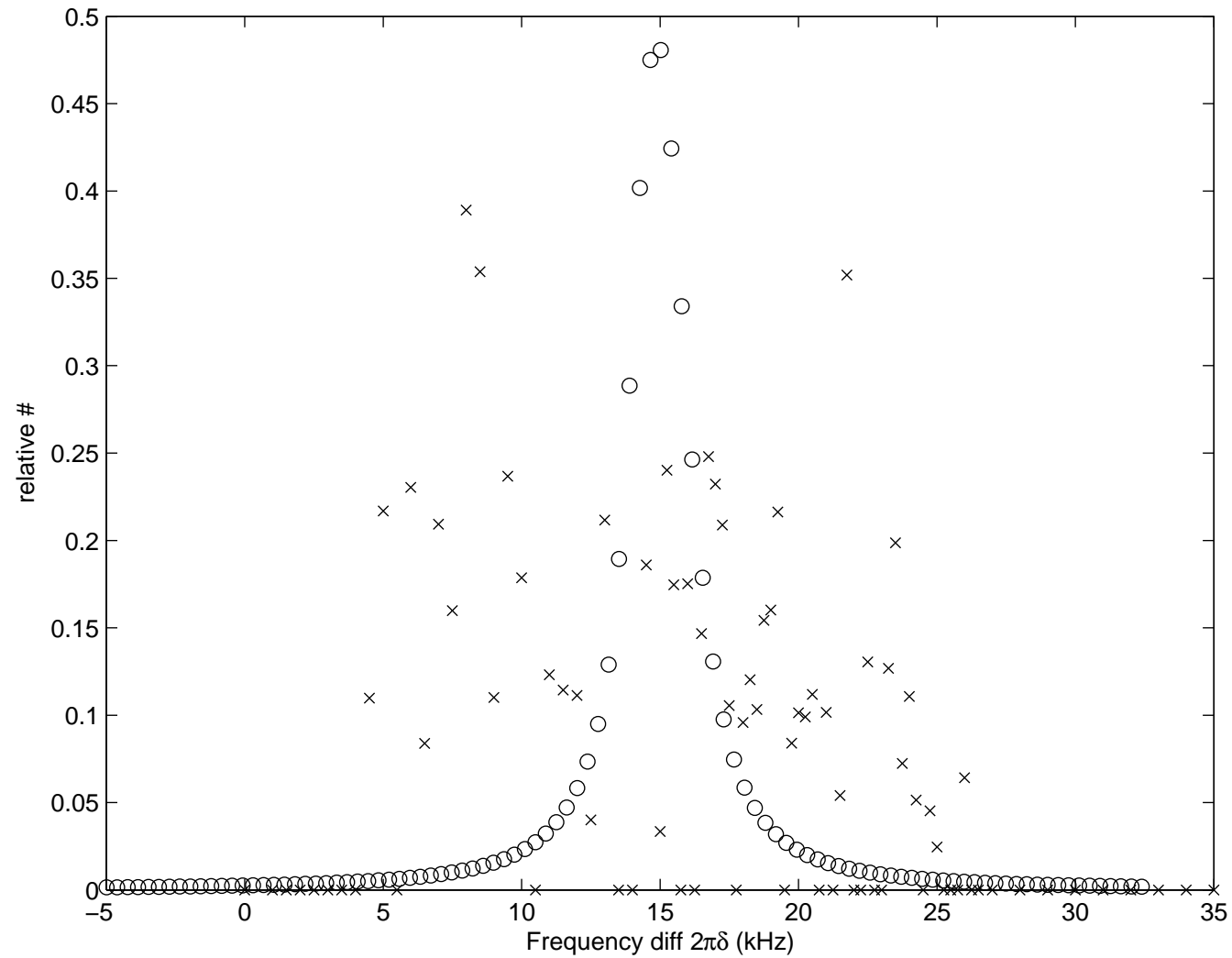
The TOP trap is a time-averaged trap.



But the instantaneous potential can't always be ignored: micro-motion.

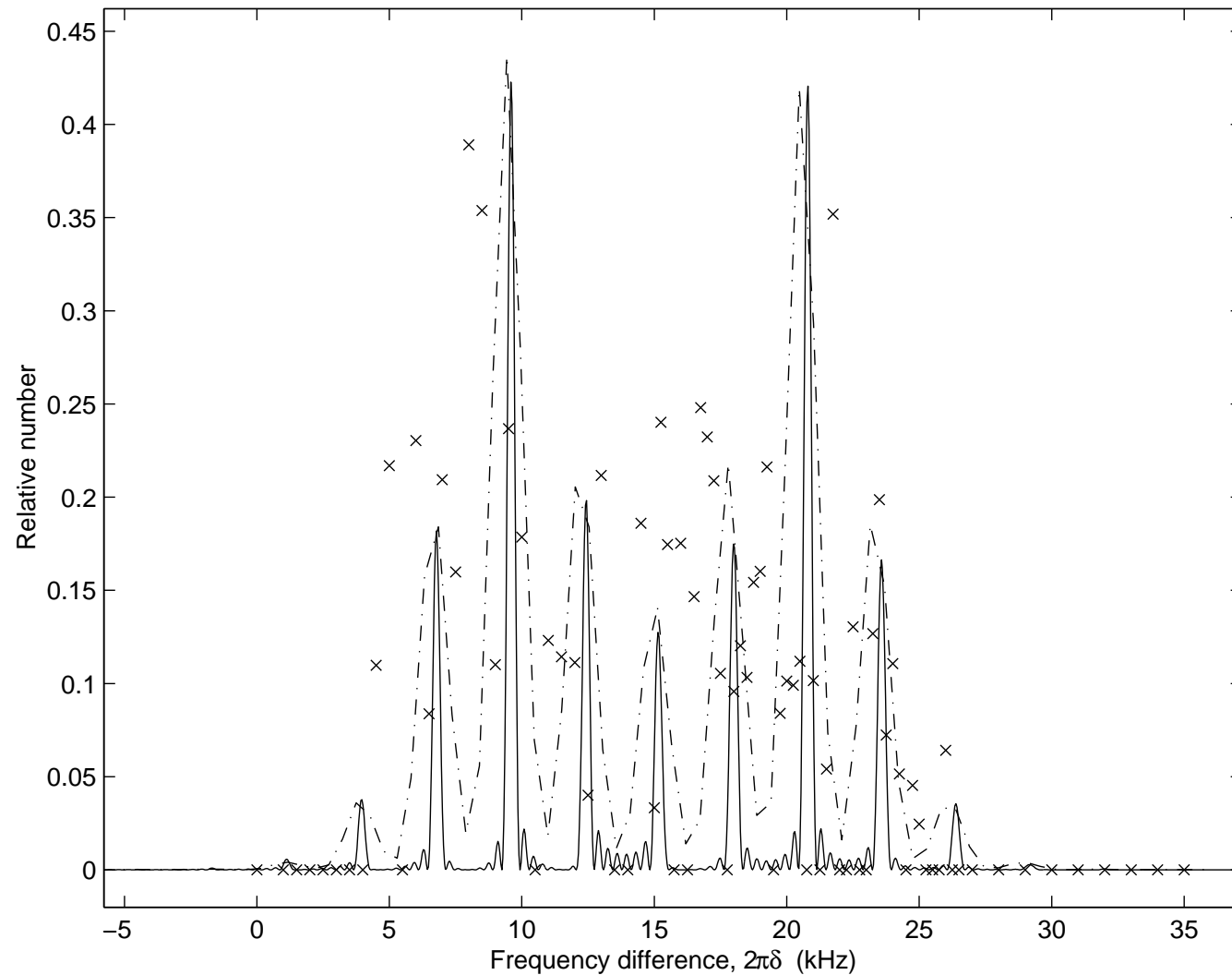
Micro-Motion and Bragg Scattering

If the condensate is moving with respect to the lattice then the Bragg resonance shifts (a Doppler shift).



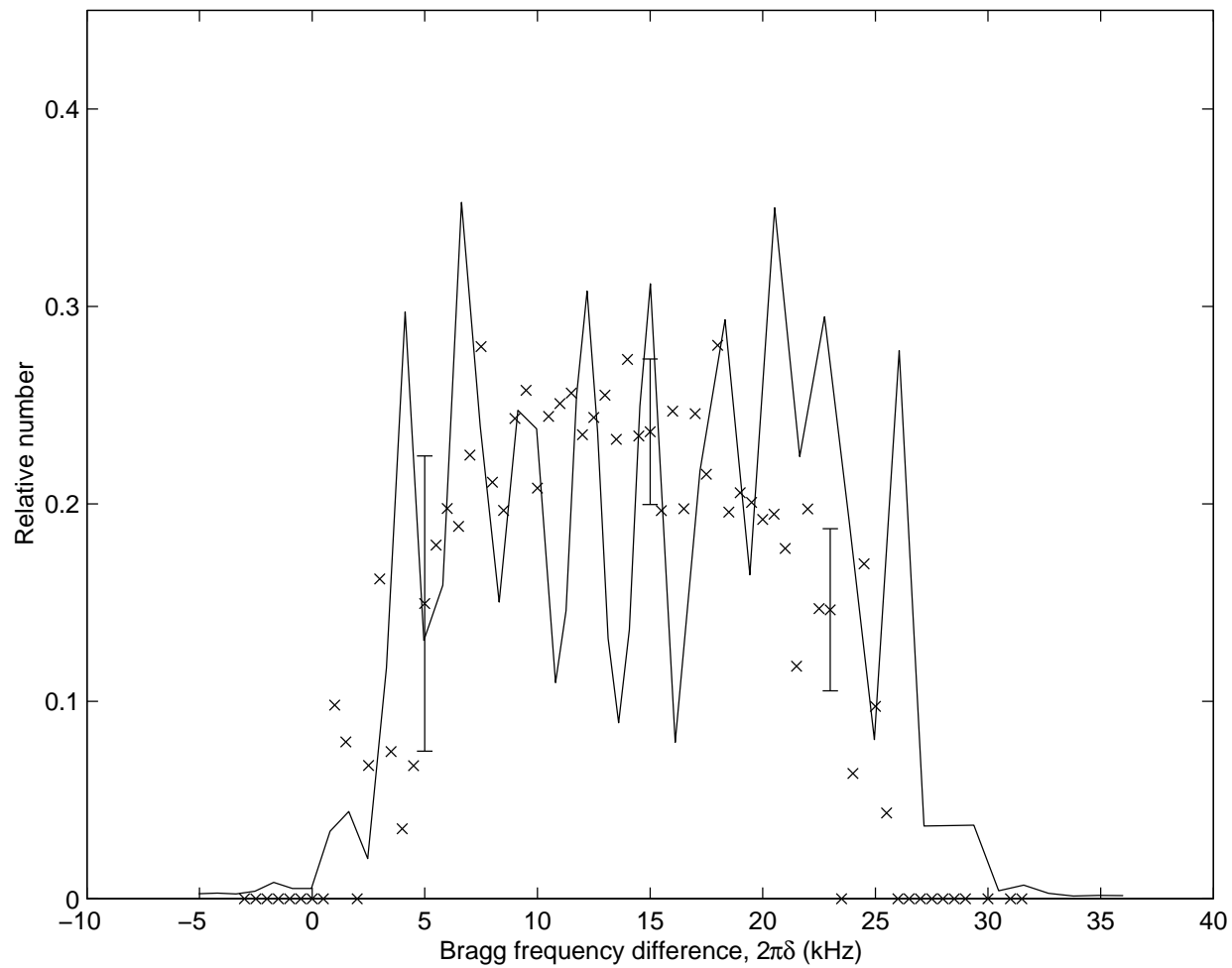
Frequency Modulation

The movement of the condensate in the lattice direction is sinusoidal. Hence the Doppler shift can be described as a frequency modulation of the resonance.



Power Broadening

Power broadening is important too, and can obscure the structure.



Summary

- Manipulation of Bragg scattering through phase shifting the lattice.
- Fast loading of the lattice ground state.
- Probing of the condensate motion via spectroscopy.